Paper

Side lobes reducing by variation of array apperture edge shape

Nikolay N. Gorobets, Yury N. Gorobets, and Victor I. Kiyko

Abstract — A possibility of side lobes level reducing in plane antenna array by creation of aperture comb edge in arrays with rectangular and circular aperture shape together with usage of different types of reducing to the array edges amplitude distributions is investigated by computer analysis. It is shown that usage of the comb structure in combination with the reducing amplitude distribution enables one to reach the side lobes level reducing in the array to $-27 \div -29$ dB.

Keywords — phone antenna arrays, side lobes level reducing

For different practical applications a problem of development of plane antenna arrays with low side lobes level (SLL) arises. This problem can be solved forming a reducing amplitude distribution of field sources in the array aperture by reducing of the field amplitude on array elements with approaching to the array edge as well as by reducing the radiators number toward the array edges by using 8-angle, rhombic or circular shape of it.

Another way to realize the reducing amplitude distribution toward the array edges by reducing the radiators number is the radiators thinning out toward the array edge. Such a thinning out can be realized accidentally or periodically.

The presented paper is a sequel of the work started in [1] on computer analysis of a possibility to reduce SLL of plane waveguide-slot antenna arrays.

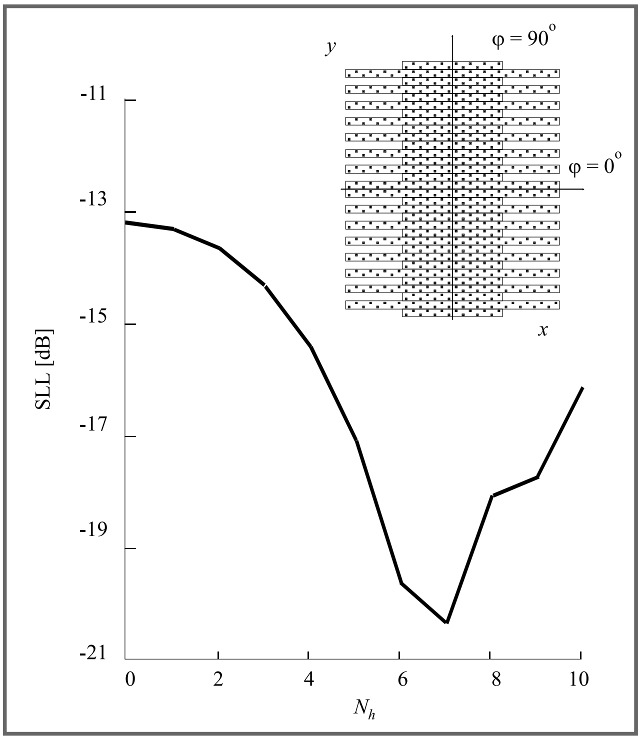

Fig. 1. SLL distribution in rectangular array with comb

Consider a case when the discussed in [1] rectangular array edge which is parallel to y-axis has not a regular shape but is designed as a comb with grooves length equal to N_h, where N_h is an integer number of the radiators excluded from the array alternately starting from its edge (antenna scheme in Fig. 1).

Let us analyse this antenna array characteristics in dependence on the groove length N_h. Firstly, we investigate a case of constant amplitude distribution of the field sources along the array elements. In Fig. 1 the distributions of maximal side lobe level in the plane $\varphi = 0$ are shown.

This is what was to be expected that in the plane $\varphi = 0$ the increase of the groove length leads to fast reducing of the maximal side lobe level from -13.2 dB for the array with regular aperture edge to -20.5 dB for $N_h = 7$. This is a case when the grooves length is equal to a quarter of the array length. Because the second side lobe level increases as a function of the groove length the maximal side lobe level is also enhanced. Moreover, the antenna Radiation Pattern (RP) is enhanced on 16.5%. In the plane $\varphi = 45°$, the side lobes keep up their level lower then -27 dB whereas in the plane $\varphi = 90°$ one can observe a considerable reducing of the side lobe on 0.7 dB. The radiators number in such an array for $N_h = 7$ reduces on 23% in comparison with a square closely filled array.

Let us apply the reducing amplitude distribution to the rectangular antenna array with aregular comb on its edge. We limit our investigation to the directivity characteristics only in the plane $\varphi = 0$, that is in the plane where an influence of the comb structure of the array aperture edge is sufficient. The analysis of side lobes level dependence on the groove length N_h under sine amplitude distribution shows that a maximal comb efficiently here is reached only when the groove length is equal to $5 \div 7$ radiators. The field amplitude on the edge array elements is lower then 0.5. Dependence of the side lobe level on parameter A_0 for the comb grooves length values equal to 0, 6 and 7 radiators is shown in Fig. 2.

One can see that for the antenna array with the comb edge of aperture under the grooves length equal to $6 \div 7$ radiators and for the sine amplitude distribution with $A_0 = 0.1 \div 0.2$ it is possible to obtain the side lobes suppression till the level -26 dB, which is on 2.5 dB more then for the same array without comb [1]. RP width here increases from 2.4° to 3.4° and the radiators number is reduced on $20 \div 23\%$.

For the case of exponential distribution the same calculation shows that minimal side lobe is reached under the grooves length $N_h = 5$ and field amplitude on the edge array elements within the limits $0.2 \div 0.6$. The side lobe level here

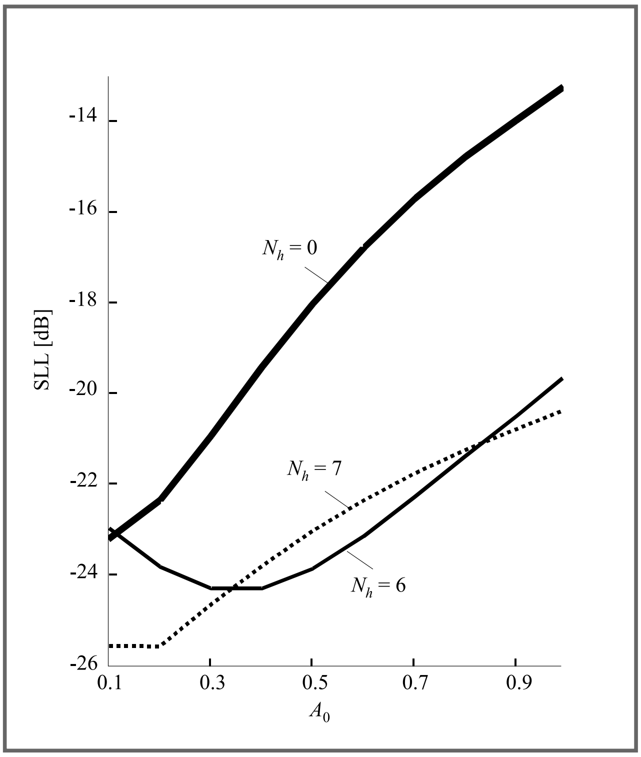

Fig. 2. SLL distribution in array with a comb and a sine amplitude distribution

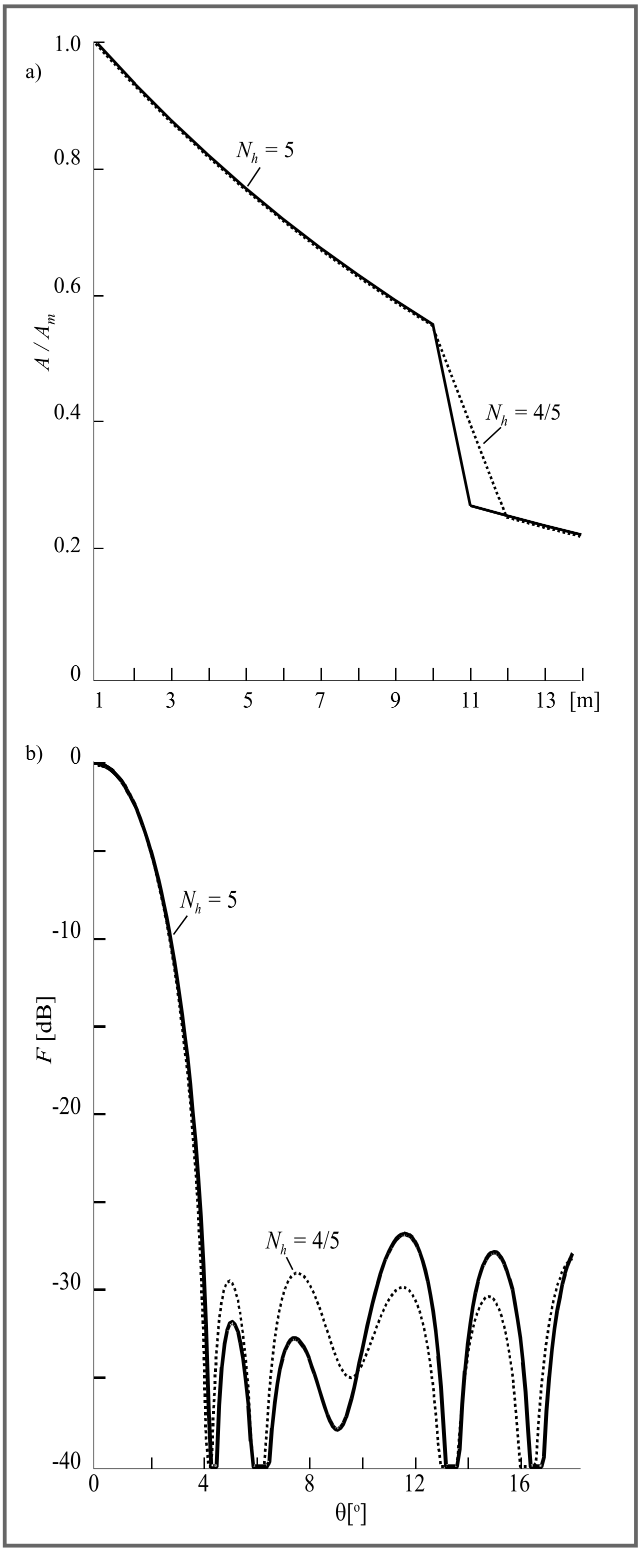

Fig. 3. Amplitude distribution on the columns of the rectangular array with comb under exponential amplitude distribution on the array elements for different grooves length (a) and the correspondent RP (b)

for $A_0 = 0.4$ is equal to -26.7 dB. This level of maximal side lobe can be reduced more if one can provide a uniform reducing of the amplitude distribution along the columns. On the border between the array regular part and its comb part an amplitude distribution jump takes place. It can be seen in Fig. 3a which is a plot of the field amplitude distribution in the array columns for the comb grooves length $N_h = 5$ and for the exponential amplitude distribution on the array elements (solid curve). To obtain the minimal side lobe the amplitude distribution in the array should be close to linear one. To eliminate the amplitude distribution jump is possible by two ways: to make a transfer from the regular part of the array to the comb one more smooth (for this it is necessary to change periodically the comb grooves length on one radiator) or to use a complex combined amplitude distribution, for example the exponential one on the regular array part and sine one on the comb part. RP in the plane $\varphi = 0$ for the case of the array with a smooth periodic changing of the comb grooves length is shown in Fig. 3b, where the solid curve corresponds to the case of the regular comb with the grooves length $N_h = 5$, whereas the dashed curve corresponds to the irregular comb with alternating grooves $N_h = 5$ and $N_h = 4$.

The correspondent amplitude distribution for the later case is plotted in Fig. 3a by a dashed line. One can see that in the array with irregular comb the maximal side lobe level is reduced to -29 dB. However, in that case the reducing of the maximal side lobe level is due to reducing the level of the third side lobe from -26.7 dB to -30 dB under a simultaneous increase of the first and the second side lobes from -32 dB to -29 dB. Therefor, if one uses sharp-directed isolated radiators in the considered plane, it is preferable to use the regular comb because far side lobe here suppresses RP of the isolated radiator.

So, for all considered cases of the side lobes reducing in the rectangular antenna array, application of the array with the irregular comb aperture edge and exponential amplitude distribution provides the most suppression of the side lobes. The side lobe here reduces from -13.4 dB to -29 dB under increasing the RP width on 28% when the radiators number reduces on 18%.

Figure 1 shows a scheme of the rectangular array with regular comb on its edge. One can easily see that such a structure provides the side lobes level reducing only in one plane. To provide the side lobe suppression in orthogonal plane for $\varphi = 90°$ it is necessary to obtain a reducing toward the edges amplitude distribution in this plane. Such a distribution can be obtained making the irregular comb with increasing grooves length toward the array edge (see the antenna scheme in Fig. 4).

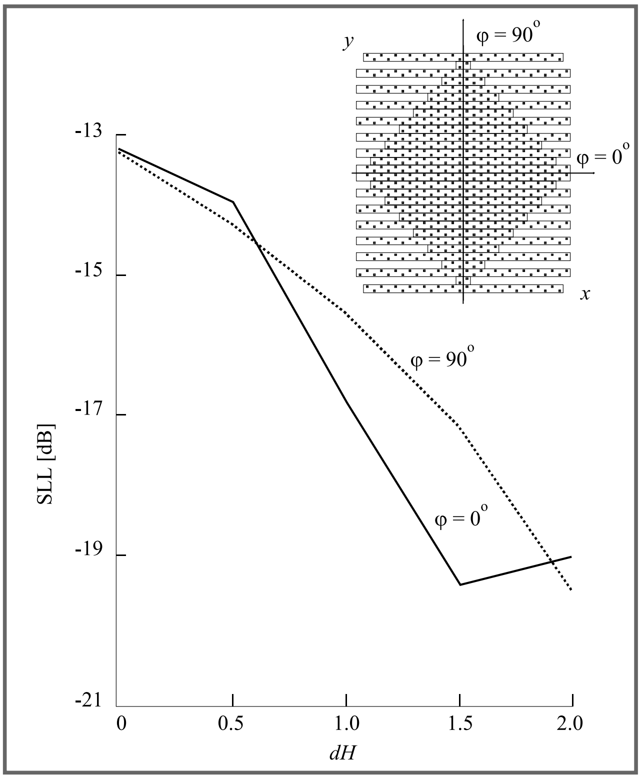

Fig. 4. SLL distribution in rectangular array with uniformly varying comb

Further we analyse the antenna array in which the grooves length of each even line varies from the array centre toward its edge on the value dH. Figure 4 shows the maximal side lobes level as a function of the parameter dH in the plane $\varphi = 0$ (solid lines) and in the plane $\varphi = 90°$ (dashed lines). In the plane $\varphi = 45°$ the side lobes level does not exceed -24 dB. As one can see from the figure, in the square array with irregular comb under maximal length of the edge grooves reaching a half of the array length ($dH = 2$), and for constant amplitude distribution on all radiators one managed to obtain RP symmetrical on all angles (with the side lobes level not higher then -19 dB. RP width here is maximal in the plane $\varphi = 0$ being equal to 2.7°. The radiators number in this case reduces on 30%.

Use the reducing toward the array edges amplitude distribution of the array on its elements. For sine amplitude distribution in the main planes $\varphi = 0$ and $\varphi = 90°$ the more the comb grooves length, the less the side lobes level reducing to $-20 \div -30$ dB in dependence on the parameter A_0, whereas in the diagonal plane $\varphi = 45°$ situation is quite the opposite: the more dH the more the side lobe level. Maximal side lobe suppression in all these three cross-sections can be observed for $dH = 2.0$. The same for all these three cross-sections level of the side lobes, being equal to -25.5 dB, takes place for $A_0 = 0.5$, whereas maximal side lobes suppression up to -32 dB in the main planes can be obtained for $A_0 = 0.2$.

For exponential amplitude distribution a dependence of the side lobes level on dH for different A_0 has more complicated character. In this case minimal (equal to -22 dB) side lobes in the main cross-sections can be obtained for $dH = 2.0$ and $A_0 = 0.3 \div 0.6$, whereas in the diagonal cross-section the side lobes level for the same conditions is equal to $-25 \div -27$ dB.

Let us investigate a circular antenna array with a comb aperture edge and a constant field amplitude on all radiators. Firstly, consider the case when the comb grooves length is the same for all grooves. Such an array scheme is shown in Fig. 5b for $N_h = 7$. Figure 5a shows the maximal side lobes level as a function of the grooves length N_h in the cross-section $\varphi = 0, 45°, 90°$. One can see that RP with axis-symmetrical side lobes is obtained for the grooves length equal to $8 \div 9$ radiators. The value of the maximal side lobe level here is equal to $-22 \div -23$ dB and RP width is within the limits $2.89 \div 3.3°$. The number of radiating elements in this array is equal to 49% in comparison with the initial square closely filled array. Figure 5b shows RP of this antenna array in three cross-sections $\varphi = 0, 45°, 90°$.

In the case when the comb grooves length in the circular antenna array is uniformly increased on the value dH by approaching to the array edge, the minimal side lobe level is more then in the former case on $3 \div 4$ dB, but RP width in the later case is less then that in the former case on about 20%.

Apply the amplitude distribution reducing toward the edges to the circular antenna array. Firstly, we consider the case of the array with equal length of all comb groves N_h and sine amplitude distribution on the array elements. Calculation results show that axial symmetry for the side lobes under their minimal values takes place in the antenna array with the grooves length N_h being within the limits $8 \div 9$ radiators. In Fig. 6, the side lobes levels as a function of A_0 for three planes $\varphi = 0, 45°, 90°$ under N_h equal to 8 (solid lines) and to 9 (dashed lines) elements are plotted. These figures analysis leads to a conclusion that axis-symmetrical RP with the same level of the side lobes in all three cross-sections cannot be designed in this case. The main cross-sections $\varphi = 0$ and $90°$ are determining here

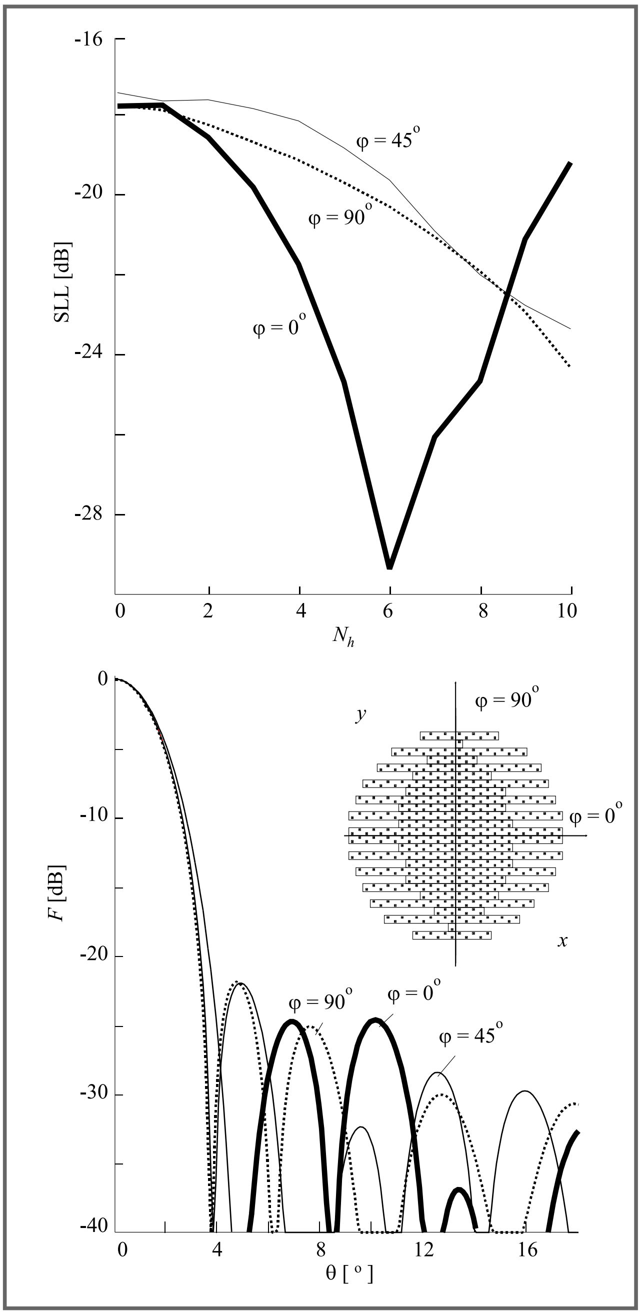

Fig. 5. SLL in circular array with comb under a constant amplitude distribution on the array elements for three observation planes (a) and the correspondent RP for $N_h = 8$ (b)

and minimal possible side lobe level is determined by its value in the plane $\varphi = 90°$ being equal to -27.3 dB for $N_h = 9$ and $A_0 = 0.1 \div 0.2$. RP width in this case is equal to $3.72 \div 3.29°$ for the angle $\varphi = 90°$.

In the case of exponential amplitude distribution, the side lobes level is equal to -24.8 dB which is more then the same in the case of sine amplitude distribution.

The analysis of circular antenna array for the irregular comb and reducing sine amplitude distribution shows that the minimal side lobe in three cross-sections can be obtained when $dH = 1.5$ and $A_0 = 0.1 \div 1.15$ and is equal to -23 dB.

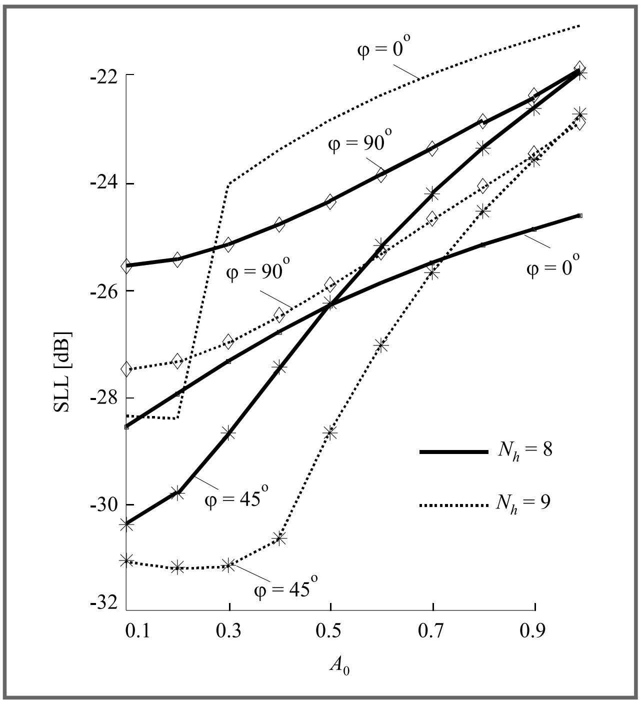

Fig. 6. SLL distribution in circular array with the comb for sine amplitude distribution

In the case of exponential amplitude distribution the minimal side lobe level in all these three cross-sections for $dH = 0.5$ and $A_0 = 0.35$ is also equal to -23 dB, $\varphi = 90°$.

The main results of the analysis of various shapes and filling densities of the array aperture calculated in order to obtain optimal side lobes level are shown in Table 1. In these cases the optimal antenna array is which provides (wherever it is possible) the axis – symmetrical (for the side lobes) radiation pattern. So, for the different planes determined by φ (for each case of the considered antenna arrays) the parameters which enable one to obtain the limit reached side lobes level much less then those in the optimal case exist.

If the axi-symmetrical (for the side lobes) radiation pattern is needed then the minimal possible side lobes equal to -27 dB can be obtained by means of the circular antenna array with regular comb on its edge and sine amplitude distribution. RP width in this case increases on about 50% whereas the radiators number reduces on 54% in comparison with the square regularly filled array. The same array with the exponential amplitude distribution provide approximately the same side lobes level but more narrow RP (on 4%) and radiating elements number increases on 5% in comparison with the previous case.

If we need to obtain the minimal possible side lobes level only in one plane then it is preferable to use the square array with irregular comb and exponential amplitude distribution. In this case the side lobes level is equal to -29 dB under RP width equal to 3.2°. The elements number here is 85% in comparison with that of the initial array.

Table 1
Parameters and characteristics of the array

Parameters and characteristics of the array		Shape of antenna array aperture: Without comb			Regular comb		Comb with uniformely increasing length of grooves		Irregular comb
		Square	8-angle	Circular	Square	Circular	Square	Circular	Square
Uniform	SLL [dB]	-13.2	-17.5	-17.8	-20.3	-23.5	-19.0	-19.0	
	$2\Delta\theta$, [°]	2.34	2.73	2.8	2.82	3.0	2.7	2.5	
	A_0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
	N	960	820	634	736	440	672	528	
	N/N_0 [%]		85	66	77	46	70	55	
	M, N_h, dH		13		7	7	2	2	
SIN	SLL [dB]	-23.3		-24.4	-25.5	-27.3	-25.5	-23.0	
	$2\Delta\theta$, [°]	3.2		3.39	3.48	3.5	3.0	3.35	
	A_0	0.1		0.1	0.2	0.2	0.5	0.12	
	N	960		634	736	440	672	578	
	N/N_0 [%]			66	77	46	70	60	
	M, N_h, dH				7	8	2	1.5	
EXP	SLL [dB]	-20.2		-23.8	-26.7	-24.8	-22.0	-23.0	-29.0
	$2\Delta\theta$, [°]	2.95		3.04	3.24	3.3	2.9	3.3	3.2
	A_0	0.3		0.5	0.4	0.5	0.45	0.35	0.4
	N	960		634	800	462	672	632	816
	N/N_0 [%]			66	83	48	70	66	85
	M, N_h, dH				5	7	2	0.5	4-5

References

[1] N. N. Gorobets, Yu. N. Gorobets, and V. I. Kiyko, „Side lobes reducing for plane antenna arrays", *Vestnik Kharkov. Univ.*, no. 405, pp. 3–10, 1998.

Nikolay N. Gorobets, Yury N. Gorobets, Victor I. Kiyko
Kharkov State University,
4 Svoboda Sq., Kharkov, 310077, Ukraine
e-mail: Nikolay.N.Gorobets@univer.kharkov.ua